What Works? An Anfis-Based Policy Evaluation Framework For Electric Vehicle Technology Development

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WHAT WORKS? AN ANFIS-BASED POLICY EVALUATION FRAMEWORK FOR ELECTRIC VEHICLE TECHNOLOGY DEVELOPMENT

ABSTRACT

The application of socio-technical transitions analysis into realms such as future sustainable mobility has revealed the requirement to understand the efficacy of policy measures ex ante. Electrification of the vehicle drivetrain has been promoted as one possible solution to achieve carbon emission and air quality targets. National governments are increasingly forming suites of policy measures to encourage electric vehicle technologies in the transport sector. To evaluate multiple policy measures, a framework based on "adaptive neuro-fuzzy inference systems" (or ANFIS) was developed and is described here. For data generation, the electric vehicle innovation policies of the European Union, United States, Japan, Germany, France and the United Kingdom were analysed and compared with the actual technology development that was measured with patent filings in those regions. The training and validation of the proposed ANFIS framework shows that the model is able to predict the development of electric vehicle technologies in terms of patent filings. The model is subsequently applied to Austria in a predictive capacity to evaluate three proposed policy scenarios. This paper concludes that the developed framework might play a significant role for assisting EV innovation policy-making by enabling ex-ante assessment the effects of different policy-mixes on the technical change.

KEYWORDS

Battery Electric Vehicles; Policy Evaluation; Socio-technical Transitions; ANFIS-Based Modelling; Austria; Sustainable Mobility.

1. INTRODUCTION

This paper presents a framework for the ex-ante assessment of policy measures based on adaptive neural fuzzy inference system (ANFIS) approach and applied to the specific case of Austria and low-carbon vehicle technologies (with a focus on electric vehicles or EVs). The emergence of a diverse array of policy measures, along with the increasingly apparent need for urgency in achieving a transition to a more sustainable mobility, means that ex-post analysis is increasingly inadequate to the task of guiding the effective choice of policy interventions.

In terms of CO_2 emissions, road transport with a growth of 36% over the 18 years to 2012 is one of the fastest growing sectors in the European Union (EU) (Pasaoglu, et al., 2012). In response, and also to comply with its commitments under the Kyoto Protocol, the EU aims to reduce overall CO_2 emissions by 20% by 2020 (as stated in the Europe 2020 strategy) and 80% by 2050 (ECF, 2010). For transport, this translates to a 60% reduction target for 2050, compared to 1990 levels (EC, 2011). To enshrine this commitment, a legislative framework was introduced with specific CO_2 reduction targets. In April 2009, the EU adopted Regulation 443/2009/EC (OJEU, 2009), which established a CO_2 emission target per manufacturer of 130 g/km for the fleet weighted average of new cars, sold by 2015. This regulation was amended in March 2014 and established a stricter emission target of 95 g/km by 2021.

It is claimed that although 2015 targets for CO_2 reduction might be achieved with incremental innovations staying within the current technical regime, the 2021 target will require more radical innovations (Geels, 2012) and that electric propulsion or e-mobility represents one viable short-term solution (Järvinen et al., 2012; Brown et al., 2010; Wyman, 2009; Orbach, and Fruchter, 2011; Fontaine, 2008; Offer et al., 2010; Eaves and Eaves, 2008) even if the outcomes are highly dependent upon the method by which electricity is generated (Hawkins et al., 2012). However, while vehicle manufacturers have invested a great deal of effort into making EV purchase and ownership propositions more aligned to that of conventional cars, with mixed success and degrees of separation from the established business model (Weiller et al., 2015), the industry has demonstrated an impressive ability to resist change (INTRASME, 2015). One reason is that EVs are especially challenging because the "benefits" of EV use accrue mainly to society in the form of reduced noise, pollution and carbon emissions, whereas the performance penalty (reduced range, long recharging time, inadequate facilities for recharging, higher purchase cost and uncertain rates of depreciation) accrue mainly to the owner or purchaser of the vehicle.

For large-scale and radical system innovation, such as the introduction of EVs by the automotive industry, there is a need for policy measures that will promote integration, coordination and collaboration between previously largely isolated actors both within the established automotive industry and outside it (Dodourova and Bevis, 2014; Holweg, 2014). Across the EU and elsewhere in the world there is a burgeoning array of policy measures have been established both to support technological development and to stimulate the market with respect to EVs, but given this diversity of interventions and claims made for one sort of intervention or another (Begley and Berkeley 2012; Mazur et al., 2015; Holtsmark and Skonhoft, 2014; Sánchez-Braza et al., 2014; Zheng et al., 2012; Zhou et al., In Press) or indeed attempts to understand why EV development has not occurred (Nykvist and Nilsson, 2015) there is a need for a systematic framework to evaluate policy effectiveness (Harrison and Shepherd, 2014; Querini and Benetto, 2014).

To this end the paper proceeds in the following fashion. In section two, consideration is given to socio-technical transitions theory and in particular to the need for operationalisation of key concepts, which in turn demands robust methodologies to establish an appropriate trajectory and pace of change. This is followed by a contextualisation of the EV case as it applies in the EU with a focus on the diversity of policy portfolios adopted by different national governments.

In section three the ANFIS methodology is explained, while section four provides the case study of with a focus on the application of the approach to the situation in Austria. Section five then gives some brief conclusions with respect to the study undertaken.

2. SOCIO-TECHNICAL TRANSITIONS IN SUSTAINABLE MOBILITY IN THE CONTEXT OF EVs IN THE EU

2.1. Social-technical transitions theory

It is recognised that a move to electric propulsion or e-mobility poses more than a technological challenge for the automotive sector (Geels, 2012). Owing to the multi-dimensional impacts of EV technologies, there is a substantial innovation literature emphasising that a successful change involves overcoming barriers that go far beyond purely technological innovation; and that economic, business, infrastructural, institutional and societal innovations are just as important (see for example Rip and Kemp, 1998; Rotmans et al., 2001; Geels, 2002; 2005a; 2005b; 2005c; 2010; Geels and Schot, 2007; Geels et al., 2012; Smith et al., 2005). Accordingly, innovation theory has evolved greatly from one focusing only on technological innovation to the one investigating innovation processes from a system perspective. This has brought more complexity into innovation theory, suggesting that attention needs to be paid also to the societal and institutional system in which an innovation is happening and spreading, leading to research on transitions of socio-technical systems (Mazur et al., 2015).

Socio-technical transitions theory posits the notion of an embedded regime in a state of dynamic equilibrium for any given ensemble of technologies and related practices (Geels, 2002). At the core of the automotive regime remain the major vehicle manufacturers and their entrenched technology packages of the all-steel body, the internal combustion engine (ICE) and a distinctive business model predicated on centralised manufacturing economies of scale, long inbound and outbound logistics lines, franchised retailers, and the outright sale of cars (and associated finance) as the primary source of revenue (reference removed for review). In other words, at the level of the vehicle manufacturers there is a suite of core product and process technologies that are combined with a distinctive pattern of value creation and capture – and it is these two aspects in combination that form the fundamental basis of the existing socio-technical regime. However, around this core has accreted a multi-layered "shell" of supportive commercial activities, social frameworks, practices, infrastructures, legal norms and enforcements, behaviours, attitudes, normative values and beliefs all of which contribute to and largely reinforce the established socio-technical regime (Steinhilber et al., 2013). Importantly, many of these accreted constituent elements act, implicitly or explicitly, to allow the reproduction of the incumbent regime as currently constituted and on the "terms" of the established regime participants. Government is not neutral in regime reproduction either (Pinkse et al., 2014). Rather, government activity participates in enabling regimes by, for example, the provision and enforcement of legal frameworks and, crucially, is a substantial beneficiary through taxes on vehicle and fuel sales, and on the earnings of those employed within the regime. Moreover, governments at national, city and local levels can be significant as buyers and operators of vehicles – particularly with regard to public transport of course.

At the theoretical level, we can observe that the socio-technical transitions literature (see the contributions in Geels et al., 2012) has a tendency to focus (in a potentially ideological manner) on the contribution of entrepreneurial new entrants or, alternatively, grassroots movements, that might establish the enclaves or destabilisation forces from which systemic change can radiate out. The realm of strategic niche management is even more expressly about such micro-level initiatives, and how they might be nurtured to achieve sustainable transitions. In contrast, incumbents tend to be regarded as the obdurate remnants of the regime that is in need of change, and that are either passive victims of change, or indeed actively resist change. Yet in the case of the automotive industry and personal private mobility we may observe that, currently at least, technological innovations are rather layered on top of (or into) the existing regime rather than displacing it - just as new practices and behaviours may be layered into existing practices. However, it is also difficult to assess the real strategies of the large car companies. For an extended period of time these companies have pursued a kind of portfolio approach in regard to alternative technologies. Previous studies showed that in fact those companies invested more (and patented more) in the ICE technology (Magnusson and Berggren, 2011, Dyerson and Pilkington, 2005, Frenken et al., 2004, Oltra and Saint Jean, 2009b, Sierzchula et al., 2012a, Sierzchula et al., 2012b, Wells and Nieuwenhuis, 2012, Wesseling et al., 2014). Averagely, around 80% of the industry's patents are thought to be awarded to ICEV related technology, against only about 20% for technologies associated with BEVs, PHEVs and HEVs (Oltra and Saint Jean, 2009b).

Moreover, the tendency to treat incumbents as a monolithic block may act to obscure divergent capacities and strategies with regard to future change, both within the regime as a whole and even within individual companies (or other regime participants) or between different spatial jurisdictions and time periods (Geels and Penna, 2015). In other words, there are certainly times when regime participants do act as a group, most obviously through consumer, trade or industry associations, but equally there may be various schisms within such a collective or individual members may take divergent stances (Sarasini, 2014; Gnann et al., 2015; Weiller et al., 2015).

The underlying assumption within transitions theory is that prescriptive policy interventions are necessary in order to stimulate and nurture new production-consumption modes, resulting in a concern for fiscal and other incentives, learning from socio-technical experimentation, consensus building, R&D support, infrastructure development, regulatory frameworks and other features (Small, 2012; Beck et al., 2013; Bakker and Trip, 2013). Significantly, it is recognised that transitions may have a distinctly spatial component (Coenen, et al., 2012), which can include national policy measures. Equally, it is recognised that transitions can have a sector component or focus (Kemp et al., 2011) and are crucially the outcome of governance structures (Nilsson et al., 2012).

However, a weakness with transitions theory is that it lacks precision when the concepts are articulated in a research or policy setting, and in particular it lacks clear methodologies and metrics to enable the evaluation of whether particular policies are contributing to transitional change, and also the trajectory and pace of that change. There are several instruments governments might use for promoting EV technologies. Such variety of instruments presents significant challenges for research seeking to generate comparative lessons about their relative impact on technological development (Dupuis and Biesbroek, 2013; Köhler et al., 2013). Therefore a key question is: which method(s) should be used for the evaluation of instruments for EV technology development? While transitions scholars have increasingly sought engagement in the policy arena, with some success, there is a need for tools to enable the pre-implementation analysis of putative policy measures intended to assist in the creation of benign path dependencies and hence (in this case) transitions to sustainable mobility.

2.2 EVs in an EU policy context

In March 2007, the European Council set clear goals on the reduction of energy consumption, renewable energy generation and emission of greenhouse gases. In setting the emission reduction goal, a 20% reduction in CO_2 by 2020, it was recognised that the transport sector, and more importantly the automotive sector had a significant role to play and a legislative framework was introduced with specific CO_2 reduction targets – down to 95 g/km fleet weighted average of new cars sold by 2021. Therefore, the pressure is on the automotive sector to adopt alternative propulsion technologies that have lower or even zero direct CO_2 emissions (Leurent and Windisch, 2011).

A complicating factor in the automotive context is the range of technological possibilities under the rubric of “low-carbon”: from vehicles with enhanced internal combustion engines (ICEs) through Battery Electric Vehicles (BEVs); Hybrid Electric Vehicles (HEVs); Plug-In Hybrid Electric Vehicles (PHEVs); Range Extended Electric Vehicles (REEVs); Fuel Cell Electric Vehicles (FCEVs); and a range of esoteric technologies such as compressed air hybrid engines that have thus far made scant impact on the industry but remain possibilities in the medium term. Additionally, fuels with varying claims to low-carbon status can also be identified such as biofuels and Liquid Petroleum Gas. In principle, electric propulsion is a market-ready technological alternative to the ICE. However, environmental innovations such as EVs have a so called “double-externality problem”, where the costs of development, deployment and use are borne by the innovator alone, although the society benefits from it as well (Santos et al., 2010; Rennings, 2000; Faber and Frenken, 2009). This problem reduces incentives for consumers and businesses alike to invest in environmental innovations.

Within the EU, considerable policy effort has been directed at resolving the double-externality problem. More broadly there have been polices targeting reduction in carbon emissions from cars (Euractiv, 2013; EVI, 2013). The 2007 European Action Plan for Energy Efficiency (2007-12) for example identified transport as one of three core areas with potential for energy savings, while Directive 443/2009 laid down the framework for CO_2/km targets. The 2011 Roadmap to a Single European Transport Area included the strong target of nil conventional ICE cars in cities by 2030. The EU fleet average carbon emissions regime is a suite of measures includes the setting of fleet average target CO_2 emissions per kilometre along with fines for non-compliance; the compulsory availability to consumers of fuel efficiency and carbon emission information; and the development of national incentives on carbon emissions reductions through vehicle taxation, benefit in kind taxation and other steps to penalise high-emitters and/or preferentially treat low-emitters. In addition, the continued popularity of EVs in economic policies, especially after the financial crisis of 2007, is recognition of EV as a potential source of the economic health of national economies (González-Torre et al., 2010). Public R&D funds such as the EU Horizon2020 programme or those provided by the United Kingdom (UK) Technology Strategy Board (now Innovate UK) are designed to support the development of appropriate new technologies and promote economic growth. For the EU, maximising SME engagement and benefit from the transition to EVs is seen as a significant means to achieve both economic growth and emission reduction targets as stated in the Europe 2020 strategy (Özel et al., 2014).

As a result, driven by the need for energy security, carbon abatement, new jobs, and economic development, most of the European Union’s largest countries have established supportive policies for the accelerated introduction of EVs (Chan, 2007; Bakker et al., 2014; Schamp, 2014; ACEA, 2015; Gnann et al., 2015). An illustrative example of measures at the national level is the 2009 National Development Plan for Electromobility in Germany which included setting a target of 1 million EVs in the national fleet by 2020 and by providing €500m in funding support (Mazur et al., 2015). The government also offers buyers up to €4,000 to buy an EV as part of a scheme to subsidize electromobility. In France the 2009 “carbon-free vehicles” plan offered an even more ambitious target of 2 million EVs on the road by 2020 and €1.5bn in total funding including infrastructure up to 2015. In France, additional measures include a €5,000 cash rebate on EV purchases, free registration, reduced overnight parking charges in public spaces, and a 2010 law that requires new residential and commercial premises with parking facilities to include recharging points. There is a commitment to deploy up to 75,000 public and 900,000 private charging stations by 2015, and 4.4 million by 2020, while also using public purchasing of vehicles to stimulate demand. Meanwhile, the French “bonus-malus” system of penalising heavy CO_2 emission vehicles in taxation while rewarding low- CO_2 emission vehicles also acts to shift the balance of the overall mix of sales. The French automotive industry has been at the forefront of EV production, notably with Renault producing the Twizy, Zoe, Fluence and Kangoo EVs and making strong corporate statements regarding the expected future share of EVs in total sales with the industrialists acting in tandem with the policy-makers (Villareal, 2011). The Paris Velib scheme has attracted much attention (Nair et al., 2012) while the EV Autolib scheme has equally prospered.

3. METHODOLOGY

In many fields, system modelling is significant as it enables the investigator to understand, simulate and predict system behaviour. In simple, straightforward interventions, linear logic models can be used to trace a stream of inputs, activities, and outputs that lead to a small, specified set of outcomes. However, the EV sector is complex socio-technical system with numerous relationships operating at multiple levels. Hence, designing innovation policies to support development of the sector presents a significant challenge. Evaluations that oversimplify relationships may miss vital factors that influence effective program implementation. The EV system as a complex socio-technical system therefore requires new frameworks, models, and methods for evaluation.

A framework based on “adaptive neuro-fuzzy inference systems” or ANFIS was therefore developed. ANFIS is a non-linear dynamic system modelling technique using the combination of neural networks with fuzzy logic (Gorrostieta et al., 2009). The idea behind neural network and fuzzy inference combination is to design a system model that uses a fuzzy system to represent knowledge in an interpretable manner and has the learning ability derived from a neural network that can adjust the membership functions parameters and linguistic rules directly from data in order to enhance the system model performance. The trained ANFIS algorithm can be adopted to predict the technology development of EVs based upon national government policy strategies.

The ANFIS approach is described in more detail below:

An adaptive neural network or ANN is an adaptive system that changes its structure on the basis of external or internal information flowing through the network during the learning phase (Hassoun, 1995). An input is presented to the ANN and a corresponding desired or target response is set at the output. An error occurs due to the difference between the desired response and the system output. The error information is then fed back into the system and the system parameters are henceforth adjusted in a systematic fashion. This process is repeated until the system performance is deemed acceptable. When this learning process is completed, the ANN parameters are fixed. However, information regarding the emerging EV industry is often expressed in qualitative terms, verbally or diagrammatically – good relationships among stakeholders, good government support and low impact innovation policies (Özel et al., 2014). This situation makes the training of the ANN model difficult. In order to gain better insight into the effects of various relationships among different innovation policies, these aspects need to be incorporated in the model. It is the use of fuzzy inference system or FIS, which adopts the fuzzy if-then rule that overcomes such a problem since FIS provides a unified framework for considering the gradual or flexible nature of variables, and representation of incomplete information (Dubois and Prade, 1995). Embedding a FIS in a general structure of an ANN has the benefit of using available ANN training methods to find the parameters of a fuzzy system. The objective is that the trained algorithm can then be used to predict the technology development of EVs (output parameter) based on national governments` different technology push and pull strategies (input parameters).

In order to develop and test the ANFIS framework, the following steps were taken:

Data Generation: The initial step in the development of the ANFIS framework involved the extensive collection of data. Governments can encourage innovation in two ways: they can implement measures that reduce the private cost of producing innovation, technology-push, and they can implement measures that increase the private payoff to successful innovation, demand-pull (Nemet, 2009). Based on this approach, an EV innovation system might be explained as a complex and dynamic system where one set of agents is empowered to push the technology forward (enterprises, academia), whilst another set (consumers) is empowered to pull the technology forwards. Although theory focuses on whether innovations are driven by technology push or technology pull, empirical evidence has shown that both strategies are important for diffusing technology into the marketplace (Schmookler, 1966; Pavitt, 1984; Nemet, 2009). Besides, this dichotomy of technology-push and demand-pull are still used frequently in policy debates to analyse the effect of policy on innovation and, hence, to design innovation policies (Peters et al., 2012, Nemet, 2009, Rennings, 2000, van der Vooren et al., 2012). Thus, "technology push" and "technology pull" instruments are used as input parameters for ANFIS framework.

In order to gather data for the input parameters, a comprehensive study of the EV innovation policies of United States, Japan, European Union, Germany, France and United Kingdom was undertaken. During the study, instruments described in Table 1 were examined (see Browne et al., 2012 and Leurent and Windisch, 2011). Next, the innovation instruments used to promote EV in the respective regions were evaluated based on an evaluation guideline (see Table 2). The evaluation guideline assigns weights to the innovation policies in order to calculate the relative performance index (RPI) of technology push and pull levels of different innovation policies. The evaluation guideline and the weightings were developed based upon the literature (see Foxon et al., 2010; Browne et al., 2012;

Auld et al., 2014). The RPI was created to compare the different innovation policies and convert the non-numeric qualitative data into a form which is able to be used for ANFIS framework.

For measuring the innovative performance of a firm or an economy, patents have been used as a valuable source of information for researchers (Griliches, 1998). Although some studies have used production models and partnerships (Bakker, 2010, Bakker et al., 2012, Frenken et al., 2004, Sierzchula et al., 2012a) as technological indicators, patents have been accepted as a better indicator for actual technological development in literature (Oltra and Saint Jean, 2009a, van den Hoed, 2005, Archibugi and Planta, 1996). According to Pilkington, Dyerson and Tissier (Pilkington, Dyerson and Tissier, p. 5, 2002) *"The use of patent information is gaining increasing attention in the fields of innovation and technology management. Patent data represent a valuable source of information that can be used to plot the evolution of technologies over time"* Therefore, in literature, patents have been used as technological forecasting indicators (Daim et al., 2006, Harell and Daim, 2009).

A patent contains the content of "technical embodiments, technology classification codes, cited information and owner information" (Choi and Hwang, 2014). Patents are not directly connected with products, but are distinguished primarily by their technical implications (Yang et al., 2013). Since most patent data are computerised, technical trends in detail (Lee et al., 2012, Campbell, 1983) technology levels, and commercial values might be understood with the patent analysis (von Wartburg et al., 2005, Yoon and Park, 2004). Besides, patents are available in large quantities in long time series allowing comprehensive longitudinal analyses (Oltra and Saint Jean, 2009a, van den Hoed, 2005, Archibugi and Planta, 1996). The innovative output and performance of countries, regions or technological fields might also be understood with patent applications (Pilkington et al., 2002, Frietsch and Schmoch, 2010). Significantly, there are very few examples of economically significant inventions which have not been patented (Van Pottelsberghe et al., 2001, Dernis and Khan, 2004).

However, it is significant to mention that patents do not truly represent the technological development of an artefact as there are other ways, exemplified by: secrets, know-how, time and cost required for duplication of the invention, learning curves. Furthermore, not all sectors use the patent as a way of protecting innovation. Yet, patent data stand as an important methodological tool (Edgar Barassa and Consoni, 2015) and patent analysis is accepted as one of the representative technology prediction method in literature (Pilkington et al., 2002). In that context, patents were chosen as the output parameter for ANFIS framework.

This study used the IPC (international patent codes) to measure the technology development of EVs. The advantage of the IPC classification is that it is application-based and thus facilitates identification of EV technology classes. The code used in this study was the B60L IPC representing "propulsion of electrically propelled vehicles" including several types of environmentally beneficial vehicle technologies). It should be noted that a number of prior studies in literature also used IPC codes to measure the technology development of EVs (see Pilkington et al., 2002; Yang et al., 2013), whilst other studies have also used patent data to demonstrate EV technology development (see Wesseling et al., 2014; Archibugi and Planta, 1996).

The results of the evaluation are shown in Table 3. As can be seen, there is a big difference among the cumulative patent applications (different scales) in different regions. The differences in patent numbers arise from the government`s efforts (policy level intervention) as well as the capability and the will of the automobile industry (firm level decisions and competition among players) to develop the EV industry in the studied regions. Therefore, it is highly technology driven and culture plays only a limited role in terms of the development of EV technologies in different regions. The policy level interventions in different countries depend on "*levels of environmental ambition, technological preferences, market regulations and the significance attached to expected co-benefits such as exploiting green jobs, energy security and industrial growth*". Specifically, *"industrial structure and presence of incumbent firms, national policy priorities to improve environmental performance and distance from the technological frontier and size of the market"* are significant factors determining the paths followed in different countries (Beltramello, 2012). In terms of firm level decisions, recent studies in literature found that companies` business strategies for introducing innovations for a particular technology such as EV are determined by companies` incentives and opportunities (Freeman and Soete, 1997, Lieberman and Montgomery, 1998, Wesseling et al., 2015).

It should be also noted that the evaluation results summarised in Table 3 were closely similar to the specified policy objectives of the regions and the development of those policy objectives over time. UK and France demonstrated more of a balance between the intensity of the technology push and pull policies, whereas Germany, USA, Japan and the EU showed a bias towards the technology push in line with their stated support of industrial growth.

Model Construction: Based on the inputs and output parameters that were explained in previous sections, the following equation was specified for developing an ANFIS model, where *i* indexes country (or region) and *t* indexes year.

$$Totalpatents_{i,\,t} = \beta_1 Totalpatents_{i,\,t-1} + \beta_2 TechnologyPush_{i,\,t-1} + \beta_3 TechnologyPull_{i,\,t-1} + \varepsilon_{i,\,t-1}$$

The dependent variable is the number of cumulative patent applications in EV technologies, whilst *TechnologyPush* and *TechnologyPull* account for the intensity of the technology push and pull activities of countries' EV policy regimes as defined by the RPI. In order to account for the difference in the tendency to innovate and patent across countries, the cumulative number of patents was standardised, whilst the introduction of the term $Totalpatents_{i,\,t-1}$, served as a "trend" variable and controlled the changes in general propensity to patent over time. All the residual variation is also captured by the error term $\varepsilon_{i,\,t-1}$. The ANFIS is capable of assigning the weights β_1, β_2 and β_3, and calculating the error automatically with its hybrid-learning algorithm. The input parameter set $Totalpatents_{i,\,t-1}$, $TechnologyPush_{i,\,t-1}$ *and* $TechnologyPull_{i,\,t-1}$ are represented by the terms $\boldsymbol{x_1}$, $\boldsymbol{x_2}$ and $\boldsymbol{x_3}$ in the ANFIS framework. Similarly, $Totalpatents_{i,\,t}$ is represented by an output vector $\boldsymbol{y}$ in ANFIS model with respect to the input parameters set $\boldsymbol{I}$, and their corresponding membership functions, set $\boldsymbol{S}$. Hence, $\boldsymbol{y=F(I, S)}$ is formulated. The structure of the ANFIS model therefore has 3 input neurons (x_1,

x_2 and x_3) and 1 output neuron (y) along with 4 hidden layers (*input membership function, rule base, membership function*, and *aggregated output*) and is shown in Figure 1.

Training and Validating the ANFIS Model: The final stage involved training and validating the model. As discussed previously, training involved learning from the data to discover the optimum operating point. However, a significant issue regarding ANNs is the over-fitting of the problem. This is because an ANN training phase captures useful information contained in the given data set and unwanted noise). To validate the model this study followed the same pathway as stated in literature in that eighty percent of the generated data set was chosen for training and the rest of the data was used for validation (see Rezazadeh et al., 2012). MATLAB software was used for the training and validating the ANFIS framework. After setting the training error tolerance to zero and training epochs to 210, training error and checking (validating) error were obtained as 0.036 and 0.052 respectively as displayed in Figure 2. This represents a satisfactory outcome for the developed framework.

Further information on the development of the ANFIS model and the training results can be found by referring to (Özel, F. and Davies, H., 2014, Özel et al., 2015)

4. AUSTRIA: A CASE STUDY

The advantage of the ANFIS framework developed here, lies in the fact that it can be used to infer a function from observations. This is particularly useful in the field of EV policy development as the complexity of socio-technical system makes the design of such a function by hand impractical. As a next step, this function was then interrogated to provide information on how changes to the input parameters (the technology push and pull instruments) would lead to changes in the output parameters (technology development measured by patent filings) within a particular system. This rational is that the additional information provided by the ANFIS framework will support national governments in developing innovation policy mixes in response to specific policy objectives.

A case study was conducted by applying the developed ANFIS framework to Austrian innovation instruments with the support of Austrian Research Promotion Agency (FFG). Austria was examined in this study as a comparative case to trial the developed framework since the automobile industry is one of the leading industrial sectors in Austria and this industry is significantly affected by the technical transition owing to the significant number of employees working in this sector (more than 175,000 people), mainly in the production and development of drive trains (Dorda and Nikowitz, 2015).

Austria is also recognised as an R&D centre for international companies such as Magna (develops EVs and plans to start mass production), Samsung SDI (manufactures battery systems for EVs and Bosch (produces electrical drives, starter motors and generators, automotive electronics etc.). Besides, Austrian company AVL employing more than 8000 people worldwide is the world's largest privately owned company for development, simulation and testing technology of powertrains (hybrid, combustion engines, transmission, electric drive, batteries and software) (ABA, 2016).

The case study is described in the following sections.

4.1. Scenario development

The Austrian Federal Government aims to further develop and direct policy instruments for the preparation of the market for e-mobility in the sense of an intelligent incentives system, so that the transition from the market preparation phase to that of launching e-mobility on the market is accelerated (BMLFUW, 2012). The FFG is the main public body to support industrial research, development and innovation in Austria and it is the biggest Austrian funding agency for applied research and therefore has a significant role to play in the technological development of e-mobility in Austria.

Since different policy priorities would result in different policy instrument mixes and, hence, would affect the development of EV technologies differently, the question then arises as to which policy instrument mix has the greatest impact on technical change? As the developed ANFIS algorithm links the technology development of EVs (output parameter) based on national governments` different technology push and technology pull instruments (input parameters), effects of different instrument mixes on the technical change can be obtained with this framework. Therefore, it provides the basis for informed decision making. In that context, three policy priorities and, thus, instrument mixes were developed to explore the potential impacts upon the technology development rates.

According to the electromobility implementation plan of Austria (BMLFUW, 2012) that was drafted after discussions with numerous stakeholders, the country`s EV innovation policy objectives were described as follows:

> *"**The targeted development of electromobility in Austria is meant to be vital in making our mobility and transport system more sustainable, more environment-friendly, and more efficient.** Electromobility can contribute significantly to the protection of the environment and climate protection as it reduces our dependence on imports of fossil energy sources. **Electromobility from Austria is an enormous opportunity, mainly for the technology and business location Austria, so as to successfully position itself, with innovative state-of-the-art technology in, say, the automotive and automotive components industries, and with intelligent energy and mobility services, on international markets.** Electromobility, therefore, is now at the centre of research, development and production, so that innovation power and ranking of Austria is enhanced, as well as added value and employment is sustainably secured. **Electromobility may finally also establish promising future-oriented options in education and training, as well as job profiles, and also create jobs and new employment opportunities.**"*

The text highlighted in bold provides the rational for the development of the three scenarios. Two of these were proposed by the FFG:

> *Scenario 1:* Promote the development of EV technologies with the prioritised short-term instruments to develop a more sustainable and greener transport system in Austria.

> *Scenario 2:* Promote the development of EV technologies by implementing all the instruments explained in the Austrian electromobility implementation plan to achieve all goals defined above.

Table 4 and Table 5 summarise the corresponding technology-push and technology-pull instrument mixes for these scenarios. To display instruments selected for each scenario, an “X” meaning that an instrument is chosen in the respective scenario was used. As can be seen, each instrument was evaluated individually based on the evaluation criteria discussed in the ANFIS Model development stages to quantitatively assess the each scenario.

Further to the above two scenarios, it is recognised that policies supporting SME development are especially important for supporting the development of EV socio-technical system. This is due to the expected changes that will occur in the established relationships within the automotive supply chain in moving from internal combustion engine to EVs, with the SMEs better positioned to develop those technologies that might have a role in the possible EV based automotive value chain re-shaping (Pilkington et al., 2002; Özel et al., 2014; Wesseling et al., 2014). Within Austria, SMEs are a key driver for economic growth, innovation, employment and social integration in addition to their crucial role in innovation and research and development (R&D). Around 298,000 SMEs account for 99.6% of all companies situated in Austria, not taken into account the field of forestry and agriculture (FFG, 2010). Thus, maximising SME engagement and benefit from the transition to EV is very significant owing to their potential in triggering economic development and innovation via the exploitation of emerging EV business opportunities. Therefore a third scenario focusing on strategically supporting

SMEs for accelerating the development of EV technologies in Austria was developed by relating results of a previous research study (Özel et al., 2014) to the different activities required to support the development of innovations (Borrás and Edquist, 2013; Edquist, 2005).

> *Scenario 3:* Promote the development of EV technologies in Austria by strategically supporting SMEs in order to create opportunities for local SMEs to become a more significant part of a future automotive regime.

The instrument mix influencing the supply and demand sides of EV market for this third scenario is summarised in Table 6 and Table 7.

4.3. Application of the ANFIS framework

In order to test the validity of the model, the first part of the study involved gathering data for Austria and checking it with the ANFIS framework.

Technology push and technology pull instruments (input parameters) used for promoting EV technologies in Austria were provided by FFG. Patent data (output parameter) for 1990-2011 periods was gathered from PATSTAT database by using the B60L IPC code. The input and output parameters were then evaluated and linked based on years. The cumulative patent applications for Austria were standardised and input-output data pairs were created. The ANFIS framework was then re-trained and Austrian data was used for checking the framework. After setting the training error tolerance to zero and training epochs to 280, training error and checking error were obtained as 0.03 and 0.055 respectively, representing a satisfactory outcome for the developed framework. This result confirmed that the framework could be applied to Austria for developing scenarios and looking at the effect of those scenarios on the innovation output.

To prepare for the evaluation of the three difference scenarios, first the relative performance index or RPI for the policy instrument mix was calculated. To arrive at the RPI figures, the technology-push and technology-pull instruments were evaluated using the framework shown in Table 1. Secondly, for the three scenarios the additional technology-push and technology-pull were also calculated in the same manner. Thirdly, the combined RPIs for each of the scenarios were calculated. These were then used as the input into the ANFIS framework.

The individual and combined RPIs are shown in Table 8 and show that the present policy mix within Austria is marginally biased towards technology-push. Although not as divergent as say Japan and Germany, this may indicate that Austria sees the development of e-mobility as being driven by industry. This fits with the stated objectives from Austria of e-mobility being both of benefit to the environment as well as the economic well-being of Austria. For scenario 1, the resultant policy mix moves towards a balance between the technology push and pull, which align with the objective of supporting a more sustainable transport choice, thus requiring greater consumer engagement. Scenario 2 moves policy mix even further to the technology pull side, which somewhat supports the observation that in previous policy mixes the preference has been towards the technology push area. Finally, scenario 3 is very much aligned to the industry support (the SME sector) and therefore biased towards the technology push area.

Following the data collection and preparation phases the trained ANFIS algorithm was used to understand how these different policy mixes may impact the development of EV technologies. The results are show in Table 9. It must be noted that the patent numbers collected using the B60L IPC are used in this context as a trend variable (the B60L code will be one of a number of codes that EV related innovation would be classified under, but would represent by far the largest share). Therefore the results are presented as standardised data (the actual numbers are also shown for reference). What is observed is that the patent filings would increase with higher technology-push and technology-pull. However, the actual increase would not be very different in the Austrian EV socio-technical system irrespective of whether the technology-push or technology-pull was the focus of change (scenario 1 cf. scenario 3). The greatest increase would be to combine all instruments in one package (scenario 2), but as noted previously this would result from a more significant increase in the technology-pull intensity relative to the increase in the technology-push intensity.

5. CONCLUSIONS

According to transitions theory, prescriptive policy interventions are needed to stimulate the development of EV technologies, and, to achieve a more sustainable mobility. However, there are numerous instruments governments might use for promoting EV technologies. The high diversity of instruments together with the increasingly apparent need for urgency in achieving a transition to a more sustainable mobility, means that ex-post analysis is increasingly inadequate to the task of guiding the effective choice of policy interventions. To evaluate various policy measures and enable the pre-implementation analysis of those measures, an ANFIS framework was developed.

The framework was developed around the innovation policies and EV technology development in the EU, United States, UK, Japan, Germany and France. The framework was shown to be able to predict the development of EV technologies (in terms of patent filings) based upon national government policy strategies. A case study was then conducted by applying the developed ANFIS framework to Austrian innovation instruments to make suggestions about Austrian future innovation policies for supporting EV technology development. This was done with the support of Austrian FFG. During the model application process, a dialogue was established with FFG to develop three different scenarios. Those scenarios were then used as inputs for the ANFIS model to calculate the effect of those scenarios on the EV technology development rates. As expected, an increase in innovation policy intensity (technology push and pull) results in a higher EV technology output (in terms of patent filings), but what was interesting was that similar EV technology output resulted from quite different policy mixes. The successful application of the ANFIS framework to these different scenarios suggested that the developed framework might play a significant role for assisting EV innovation policy-making by enabling ex-ante assessment the effects of different policy-mixes on the technical change – and hence there is latitude for alternative policy provisions according to national circumstance and preferences. It is an illustration of the ways in which future policy development for socio-technical transitions might also be informed, in the automotive and also in other sectors.

A further development could be the combination of the ANFIS framework with a qualitative cost benefit analysis in order to understand how policy mix intensity relates to the ability to fund policy actions and to capture the benefit that accrues. A limitation of such a qualitative analysis is that it produces comparative assessment as opposed to actual quantitative values, but it might prove useful in providing some comparison between the various options.

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FIGURES

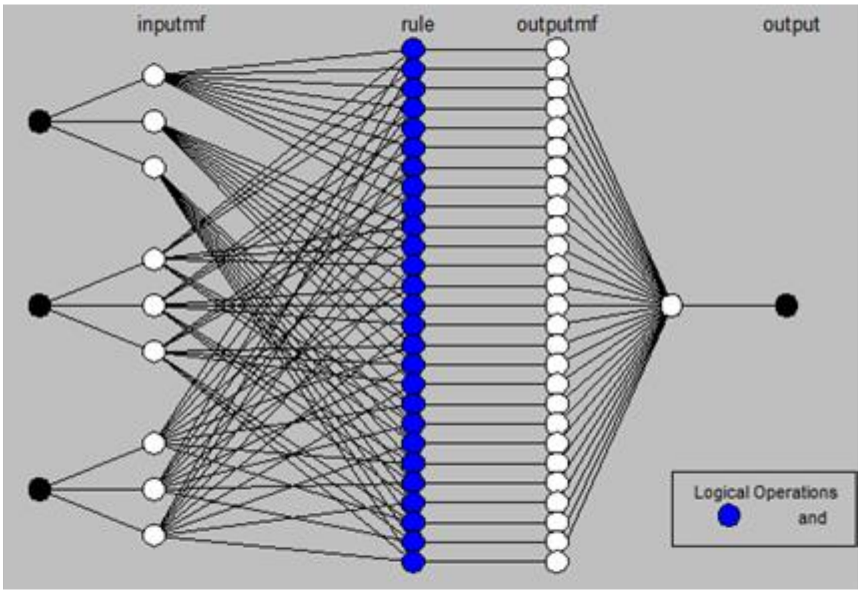

Figure 1: ANFIS Model Structure

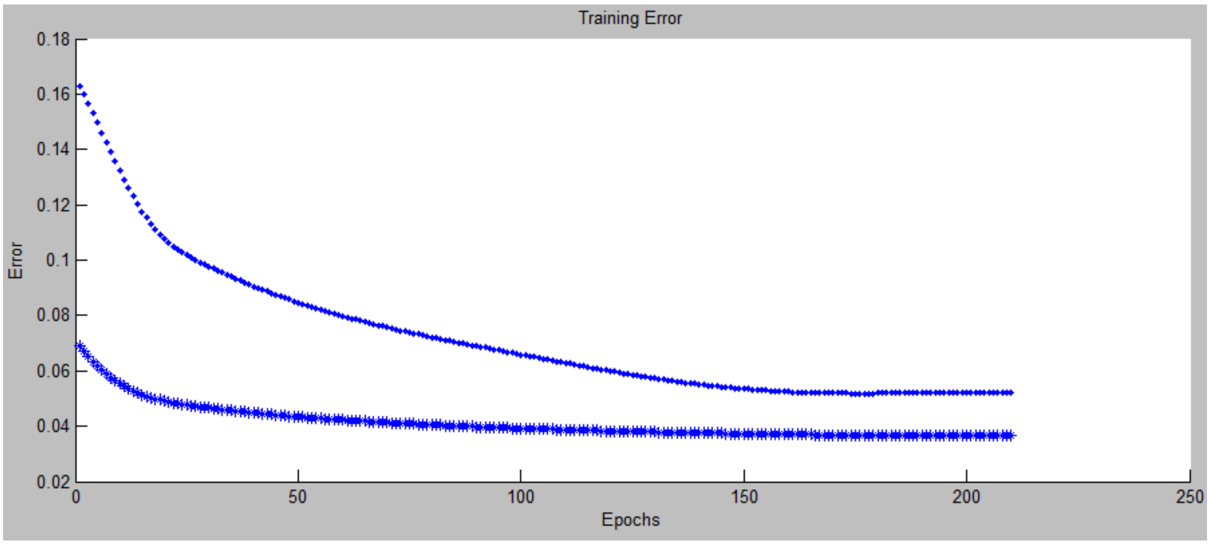

Figure 2: Training and checking error during training

TABLES

Table 1: Instruments for promoting innovation in EV field. Adapted from (Browne et al., 2012, Leurent and Windisch, 2011)

Instruments for Promoting Innovation in EV Field	*Instrument Typology*	*Technology Push/Pull*
Tax incentives	Economic and Financial	Technology Pull
Subsidies, Staggered payment schemes	Economic and Financial	Technology Pull
Infrastructure Subsidies	Economic and Financial	Technology Pull
Purchase of EVs by the government	Economic and Financial	Technology Pull
Mandatory use in public sector fleet	Regulatory	Technology Pull
R&D investments for storage	Economic and Financial	Technology Push
R&D investments for infrastructure	Economic and Financial	Technology Push
Demonstration programmes	Soft	Technology Push
Infrastructure investments	Economic and Financial	Technology Pull
Public-private partnerships, Network management	Soft	Technology Push/Pull
Emissions regulations	Regulatory	Technology Push
Long term goals and visions, technology roadmaps	Soft	Technology Push/Pull
Traffic regulations (Free Parking, Bus lane access)	Regulatory	Technology Pull
Consistent codes and standards	Regulatory	Technology Pull
Market advertising, Eco-labelling of vehicles	Soft	Technology Pull
Awareness campaigns, Education and Training	Soft	Technology Pull
Lobbying activities	Soft	Technology Pull
Targeting niche markets	Economic and Financial	Technology Push
Patent Regulations	Regulatory	Technology Push

Table 2: Weight Coefficients for the Evaluation of EV Innovation Policies. Adapted from (Foxon et al., 2010; Browne et al., 2012; Auld et al., 2014)

Weight Coefficients for the Evaluation of EV Innovation Policies		
	Instrument Characteristics	*Weight Coefficients*
Time-Frame	More than five years	0.5
	Less than five years	0.48
Reporting	Voluntary reporting	0.05
	Mandatory reporting	0.57
Policy Instruments for EVs	Tax incentives	1.04
	Subsidies, tax incentives, staggered payment schemes	1.04
	Infrastructure subsidies	1.04
	Purchase of EVs by the government	1.04
	Mandatory use in public sector fleet	0.88
	R&D investments for storage	1.56
	R&D investments for infrastructure	1.56
	Demonstration programmes	0.98
	Infrastructure investments	1.56
	Public-private partnerships, Network management	0.98
	Emissions regulations	1.32
	Long term goals and visions, technology roadmaps	0.49
	Traffic regulations (free parking, bus lane access)	0.88
	Consistent codes and standards	0.44
	Market advertising, eco-labelling of vehicles	0.49
	Awareness campaigns, education and training	0.49
	Lobbying activities	0.98
	Targeting niche markets	1.56
	Patent Laws	1.32
Stage of Activity	Planning	0.54
	Performance	0.44
	Acting	0.57
Target of Policy	Industry or professional association	0.52
	Government	0.42
	Firm	0.48
	Citizen	0.52
Source of Authority	Threat of hierarchy	0.33
	Network coercion	0.41
	Market (customer demand)	0.55
	Hierarchy (state)	0.54

Table 3: Evaluation of technology push/pull intensity and patent applications for the regions analysed

Year	UK			France			Germany			EU			US			Japan		
	Push	Pull	Patents	Push	Pull	Patents	Push	Pull	Patents	Push	Pull	Patents	Push	Pull	Patents	Push	Pull	Patents
1990	0	0	11	0	0	14	0	0	113	0	0	60	7.44	7.45	84	3.55	0	761
1991	0	0	23	3.06	0	34	0	0	271	0	0	131	15.09	10.87	185	6.71	0	1645
1992	0	0	43	3.06	3.52	66	0	0	468	0	0	224	18.64	14.35	339	15.23	0	2677
1993	0	0	65	3.06	3.52	99	0	0	706	0	0	326	22.90	17.87	500	19.49	4.26	3770
1994	0	0	84	3.06	3.52	127	0	0	960	4.24	0	428	22.90	17.87	738	19.49	4.26	4690
1995	0	0	108	3.06	5.99	161	0	0	1165	4.24	0	518	22.90	17.87	970	19.49	7.90	5669
1996	0	0	122	3.06	5.99	199	0	0	1448	4.24	0	642	22.90	17.87	1218	23.04	11.62	6589
1997	0	0	149	3.06	9.41	224	0	0	1739	4.24	0	801	22.90	17.87	1471	27.30	11.62	7641
1998	0	0	176	3.06	9.41	256	0	0	2033	11.72	0	966	22.90	17.87	1737	31.19	15.36	8865
1999	0	0	197	3.06	9.41	300	0	0	2357	11.72	0	1174	26.42	17.87	1998	34.85	15.36	10058
2000	0	0	206	3.06	12.60	338	0	3.19	2746	11.72	3.19	1403	26.42	21.06	2407	38.01	18.50	11234
2001	0	3.19	239	3.06	12.60	381	0	3.19	3155	11.72	3.19	1696	30.66	21.06	2844	41.27	22.12	12567
2002	0	3.19	264	7.30	12.60	432	0	3.19	3583	15.96	3.19	1956	33.82	21.06	3398	41.17	22.12	13904
2003	3.52	3.19	293	7.30	12.60	509	0	3.19	3993	19.61	3.19	2251	37.95	21.06	3979	44.69	22.12	15622
2004	3.52	3.19	317	7.30	12.60	578	0	3.19	4323	23.26	3.19	2497	37.95	21.06	4661	44.69	25.31	17272
2005	7.04	6.38	341	10.82	12.60	642	4.26	3.19	4602	26.42	3.19	2775	37.95	24.80	5421	48.58	25.31	19000
2006	7.04	6.38	357	10.82	15.79	696	8.39	3.19	4873	26.42	3.19	3092	37.95	24.80	6093	48.58	25.31	20948
2007	14.82	9.89	386	13.98	15.79	759	19.20	3.19	5171	34.10	6.93	3487	41.84	24.80	6764	56.34	25.31	23158
2008	22.23	9.89	421	22.11	23.27	831	22.57	3.19	5480	49.38	6.93	3900	54.56	24.80	7398	56.34	25.31	25779
2009	36.97	17.26	457	36.48	23.27	915	38.84	6.93	5786	56.43	6.93	4359	69.02	35.90	7966	64.12	29.05	28389
2010	40.49	21.00	503	40.74	33.81	1017	55.49	13.25	6324	59.59	17.91	5049	73.28	35.90	8673	81.72	43.38	31272
2011	40.49	36.38	543	40.74	37.55	1184	55.49	13.25	7026	62.75	20.97	6047	77.04	42.61	9407	81.72	43.38	34667

Table 4: Technology-Push Instruments for Scenarios 1 and 2

Typology	*Instrument*	*Activities*	*RPI*	*Scenario 1*	*Scenario 2*
Soft instruments	Demonstration programmes	Awareness-raising campaigns for electromobility are to be initiated simultaneously. An important aspect is the demonstration of electromobility as the new, contemporary multi-modality (Designing new demonstration programmes)	3.68	X	X
Soft instruments	Technology Roadmaps	Working out a joint communication strategy to foster electromobility in time and step-by-step. Additionally, regular updating of the Austrian electromobility roadmap in cooperation with the domestic research institutions and the industry	3.03		X
Soft instruments	Long term goals and visions	Analysis of long-term potentials of hydrogen and identification of obstacles related to eco-efficient hydrogen production and hydrogen infrastructure as well as any potentials of added value for Austria.	3.03	X	X
Economic and financial instruments	R&D Investments	Strengthen and further develop the focal promotion points for R&D, especially for all battery powered, hybrid-electric and fuel cell-driven vehicles. Pushing the focal point electromobility in already present instruments to promote research between universities and non-university research institutions with the industry.	4.26	X	X
Soft instruments	Network Management	Setting up a coordination group of ministries and research funding agencies for the technical orientation, optimisation and simplification of electromobility-related programmes and procedures. Here, information gained by experience so far is exchanged and future developments of the electromobility-relevant stakeholders are discussed.	3.52	X	X
Economic and financial instruments	Creation of niche markets	Development of technology competence for recycling procedures and the recovery of materials in Austria and extending competence for substitution technologies and appropriate organisational concepts. For this aim, the establishment of business locations focussing on material recovery such as rare earths and other materials in Austria will be supported.	4.17		X
Economic and financial instruments	Creation of niche markets	Supporting investments, production and new industrial settlement in the field of electromobility from Austria focussing on established funding and support instruments.	4.17		X
Soft instruments	Network Management	Supporting the international cooperation of Austrian institutions and enterprises in the fields of R&D as well as the enhanced integration of electromobility activities and projects in European and international demonstrations (for instance within the framework of bi- and multi-national ERA-Net invitations to tenders)	3.65	X	X
Soft instruments	Education and Training	Support to develop skills for intelligent production technologies and processes, especially for the flexible and competitive production of small, medium and large numbers of EVs and e-infrastructures. Development of existing support for enterprises training apprentices. Hence, a training module “e-vehicle” in the apprenticeship automobile technology is aimed to be implemented. Implementation of a course system is also aimed to promote trainers to create a sufficient number of apprentice jobs.	3.19	X	X
Soft instruments	Education and Training	Establishing practical research trainings for young researchers in the field of electromobility. Strengthening international cooperation in education and research with leading universities and research institutions in Europe, USA, and Asia.	3.19		X

Table 5: Technology-Pull Instruments for Scenarios 1 and 2

Typology	*Instrument*	*Activities*	*RPI*	*Scenario 1*	*Scenario 2*
Regulatory instruments	Consistent codes and standards (charging stations)	Specifying relative necessary minimum standards relating safety regulations of the charging infrastructure. The drafting of recommendations and directives for the set-up of public and semi-public charging stations. The drafting of recommendations for fast charging points in Austria with highly frequented and user-friendly locations. Drafting recommendations for the harmonisation of the framework conditions and procedures for the set-up and the operation of charging stations jointly with all federal provinces.	3.01	X	X
Regulatory instruments	Consistent codes and standards (Parking facilities)	Drafting of national recommendations and planning basics for garages on the basis of technical requirements specifying the adaptation of construction and design regulations for user-friendly parking facilities with regard to access, authorisation, and billing systems for EVs. Besides, drafting planning basics and construction regulations for secured and unsecured parking facilities for one-track e-vehicles such as e-bikes and e-mopeds, and drafting recommendations for features relevant to electromobility such as charging stations and bicycle boxing	3.01	X	X
Economic and financial	Infrastructure investments	Further development of the support of business and community charging stations following the criteria catalogue specifying charging infrastructure requirements, focussing especially on enhanced system effects. Existing and developing model regions are correlated to make use of knowledge gained relative to regionally and ecologically focused applications to support any implementation in the whole country.	4.26		X
Economic and financial	Subsidies	Direct support is to be examined, further developed, and continued with regard to the present e-vehicle categories. Moreover, new vehicle classes such as the REX/REEV, and PHEV will be included.	3.74		X
Economic and financial	Tax incentives	If feasible, retaining the exemption of the standard fuel-based vehicle consumption tax (NoVA) and the engine power-related vehicle insurance tax, as well as the review of the general taxation framework for EVs.	3.74	X	X
Economic and financial	Purchase of EVs by government	Existing structures for the purchase of innovative products by the public sector with Austrian federal procurement agency are to be used increasingly (Extending efforts).	3.64		X
Soft instruments	Awareness campaigns	Integration of electromobility strategies and concepts within a study in the tourism strategy process at national level. For example, tourism communities can rent EVs for users so that they can be tested.	3.19	X	X
Soft instruments	Network Management	Participation in international panels and committees in the preparation of normative standards for the construction, measuring, and registration regulations of vehicles.	3.52	X	X
Soft instruments	Eco-labelling of vehicles	Examination of options for the provision of information and labelling of the positive effects on the environment and climate before and when vehicles are purchased. To quantify and monitor the effects of electromobility on the environment, the necessary basic data will have to be compiled. Transport-related data and models in the area of electromobility are to be expanded. The information on e-vehicles available on the market also enhanced by using existing structures such as the internet platform www.autoverbrauch.at	3.19	X	X
Regulatory instruments	Traffic regulations (Bus Lane Access)	Drafting requirements and recommendations of electromobility for the traffic and area planning and making the traffic framework conditions attractive for EVs. Here, review and adaptation of federal matters such as Road Traffic Code, Motor Vehicles Act and other respective regulations are aimed.	3.58		X

Soft instruments	Awareness campaigns	Raising awareness of engineers and technicians for attractive career options (“technical career ladder”) for electromobility. Raising awareness within the framework of traffic education of children, also when young people take their voluntary bicycle test, especially with a view to inter-modality and school mobility. Raising awareness and making available of information relative to EVs in residential areas to improve road safety.	3.19		X
Soft instruments	Education and Training	Adaptation and upgrading of existing curricula, as well as education and training of teacher teams in electromobility at schools to establish the electromobility subject. Besides, drafting a “train-the-trainer” concept for the qualification of teachers in schools.	3.19		X
Soft instruments	Education and Training	Setting up training programmes for the staff in trading and selling, operation and maintenance of EVs to make them familiar with the requirements of electromobility.	3.19		X
Soft instruments	Education and Training	Learning to drive EVs will become an integral part in driving schools. Hence, appropriate further training programmes are to be developed for driving instructors, and teaching materials and test catalogues for driving licence tests are to be adapted	3.19		X
Soft instruments	Technology roadmaps	Collating and drafting of national positions vis-à-vis the energy and charging infrastructure by the ÖVE (Austrian Electrotechnical Association)/ASI joint working group (JWG), with electromobility on the agenda.	3.03	X	X

Table 6: Technology-Push Instruments for Scenario 3

Typology	*Instrument*	*Activities*	*RPI*
Soft instruments	Demonstration programmes	Designing new demonstration programmes with the objective of supporting SMEs	3.68
Soft instruments	Technology Roadmaps	Working out a joint communication strategy with SMEs to foster electromobility in and from Austria in time, and, step by step. The Austrian electromobility roadmap is also regularly updated in cooperation with all relevant stakeholders	3.03
Economic and financial instruments	R&D Investments	New R&D investments are provided to develop hybrid, battery electric and fuel-cell electric vehicles. Research between universities and non-university research institutions with the industry is also supported	4.26
Soft instruments	Network Management	New R&D investments are provided to develop hybrid, battery electric and fuel-cell electric vehicles. Research between universities and non-university research institutions with the industry is also supported	3.52
Economic and financial instruments	Creation of niche markets	Development of technology competence for recycling procedures and the recovery of materials in Austria and extending competence for substitution technologies and appropriate organisational concepts by supporting SMEs in these areas	4.17
Economic and financial instruments	Creation of niche markets	Supporting investments, production and new industrial settlement in the field of electromobility with the focus on SMEs.	4.17
Soft instruments	Network Management	Supporting investments, production and new industrial settlement in the field of electromobility with the focus on SMEs.	3.65
Soft instruments	Education and Training	Supporting SMEs to develop skills for intelligent production technologies and processes, especially for the flexible and competitive production of small, medium and large numbers of EVs and EV infrastructures. A training module “e-vehicle” in the apprenticeship automobile technology is aimed to be implemented. Implementation of a course system is also aimed to promote trainers to create a sufficient number of apprentice jobs.	3.19
Soft instruments	Education and Training	Supporting SMEs to develop skills for intelligent production technologies and processes, especially for the flexible and competitive production of small, medium and large numbers of EVs and EV infrastructures. A training module “e-vehicle” in the apprenticeship automobile technology is aimed to be implemented. Implementation of a course system is also aimed to promote trainers to create a sufficient number of apprentice jobs.	3.19
Regulatory Instruments	Patent Regulations	Patent regulations are reviewed and specific SME technology protection measures are designed	3.99

Table 7: Technology-Pull Instruments for Scenario 3

Typology	*Instrument*	*Activities*	*RPI*
Regulatory instruments	Consistent codes and standards	Developing standards for the set-up and operation of charging stations in Austria	3.01
Regulatory instruments	Consistent codes and standards	Developing standards for the parking facilities of EVs	3.01
Economic and financial instruments	Subsidies	Direct support is to be examined, further developed, and continued for EVs	3.74
Economic and financial instruments	Tax incentives	Exempting EVs from the standard fuel-based vehicle consumption tax (NoVA) and the engine power-related vehicle insurance tax	3.74
Soft instruments	Network Management	Participation in international panels and committees in the preparation of normative standards for the construction, measuring, and registration regulations for EVs	3.52
Economic and financial instruments	Infrastructure investments	Further development of the infrastructure investments for installing the necessary charging facilities for EVs	4.26
Soft instruments	Education and Training	Adaptation and upgrading the existing curricula, as well as education and training of teacher teams in electromobility at schools to establish the electromobility subject and create awareness	3.19
Regulatory instruments	Traffic regulations (Bus Lane Access)	Making the traffic framework conditions attractive for EV users. Thus, federal matters such as Road Traffic Code, Motor Vehicles Act and other respective regulations are reviewed and changed	3.58
Economic and financial instruments	Purchase of EVs by the government	Supporting SMEs by purchasing innovative products of SMEs with Austrian federal procurement agency	3.64

Table 8: Contribution of Each Scenario to RPIs of Technology Push and Pull Levels of Austrian Innovation Policies

RPIs		*Contribution of Each Scenario to RPIs*			*Total RPIs*	
Push	Pull	Scenarios	Additional Push	Additional Pull	Total Push	Total Pull
29.01	21.84	Scenario 1	21.33	22.69	50.34	44.53
29.01	21.84	Scenario 2	35.89	50.67	64.9	72.51
29.01	21.84	Scenario 3	36.85	31.69	65.86	53.53

Table 9: ANFIS Model Results for Each Developed Scenario

ANFIS Model Results					
Scenarios	Total patent filings in 2011 Cumulative Standardised (Unstandardized)	Total Push	Total Pull	Predicted Patent Filings Cumulative Standardised (Unstandardized)	Effect of Each Scenario on Patent Filings
Scenario 1	1.54 (648)	50.34	44.53	1.89 (720)	72
Scenario 2	1.54 (648)	64.9	72.51	2.62 (872)	224
Scenario 3	1.54 (648)	65.86	53.53	1.95 (733)	85